Statistical approaches to the evaluation of the impact of vaccination programs: a case study exploring rotavirus vaccination in New South Wales

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Certificate of Original Authorship

I, Nicole Mealing, declare that this thesis is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Faculty of Health at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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List of Abbreviations

ACT	Australian Capital Territory
AGE	Acute Gastroenteritis
AIC	Akaike's Information Criterion
APDC	Admitted Patient Data Collection
AR	Autoregressive
ARMA	Autoregressive Moving Average
ARIMA	Autoregressive Integrated Moving Average
CI	Confidence Interval
ED	Emergency Department
EDDC	Emergency Department Data Collection
GP	General Practitioner
HBeAg	Hepatitis B Envelope Antigen
HBsAg	Hepatitis B Surface Antigen
ICD-9	International Classification of Diseases Ninth Revision
ICD-10	International Classification of Diseases Tenth Revision
ICD-10-AM	International Classification of Diseases Tenth Revision Australian Modification
MA	Moving Average
NSW	New South Wales
NT	Northern Territory
PCV7	7-valent Pneumococcal Conjugate Vaccine
QQ-plot	Quantile-quantile plot
Qld	Queensland
RCT	Randomised Controlled Trial
RSV	Respiratory Syncytial Virus

RV	Rotavirus
SA	South Australia
SNOMED CT	Systemised Nomenclature of Medicine Clinical Terms
US	United States
Vic	Victoria
WA	Western Australia

Abstract

Vaccination programs can provide an effective means to control infectious diseases at a population level. Evaluating the impact of these programs after implementation can be complicated by limitations of routine surveillance systems and lack of routine testing to confirm diagnosis, as well as natural fluctuations in disease rates over time. This thesis provides a structured explanation of statistical methods and how they can be used to address the epidemiological challenges in assessing changes in burden of disease as a result of vaccination programs. It explores statistical approaches to the evaluation of vaccination programs at a population level, using rotavirus vaccination in New South Wales (NSW), Australia, as a case study.

A summary of the key features that need to be considered when trying to detect any changes in the burden of infectious diseases due to vaccination is given. An assessment of the impact of the Australian rotavirus vaccination program, introduced in 2007, on hospitalisations and emergency department (ED) presentations of children aged under five years for all-cause gastroenteritis in NSW from July 2001 to June 2013 was conducted. Previously published methods that separate these hospitalisations and ED presentations into those due to rotavirus and those that are not are compared. A simulation study is used to explore these methods in controlled scenarios to determine the most appropriate method for these data.

The Australian rotavirus vaccination program had an almost immediate impact and led to a fifty and sixteen percent reduction in the rate of hospitalisations and ED presentations for acute gastroenteritis within the first 2.5 years. These declines were mostly attributed to a decline in the size of the seasonal peak. The methods to determine rotavirus cases from all-cause

gastroenteritis cases had different strengths and limitations and the derived estimates varied. No robust method was identified from the simulation study for our data. Each method that relied on using weekly counts of positive rotavirus laboratory tests to estimate rotavirus-attributable cases underestimated the true number of rotavirus cases when their assumptions held.

The evaluation of the effectiveness of vaccination programs requires the use of rigorous statistical methods to ensure the robustness and validity of findings. Appropriate statistical methods that account for temporal trends are needed to provide a detailed understanding of any changes in disease burden observed. While this thesis focused on rotavirus disease burden in NSW, Australia, many of the concepts discussed are applicable to other infectious diseases.